Accordingly, various embodiments effectively increase and enhance the back barrier in the GaN buffer layer and enhance the off-state breakdown voltage characteristics in the provided AlGaN/GaN HEMT structures and devices.

[0011] In one non-limiting embodiment, a HEMT comprises a Schottky gate controlled 2DEG channel, an ohmic source contact and an ohmic drain contact. Advantageously, fluorine ion implantation can be performed prior to the gate metallization of the device after lithography, according to an aspect. As a result, the enhanced back barrier is self aligned with the gate metal.

[0012] In other embodiments, post-growth methodologies are provided for fabricating EBB HEMT heterostructures according to various aspects of the disclosed subject matter. The provided structures and devices can be created according to aspects of the disclosed subject matter by selectively implanting fluorine ions in developing structures (e.g., post-epitaxial growth). Advantageously, the described fluorine ion implantation operation is made available by commercial ion implantation equipment providers.

[0013] Further, one or more embodiments of HEMT heterostructures are described that incorporate an EBB layer or region comprised of implanted fluorine ions located substantially below the prospective gate location of developing EBB HEMT heterostructures. For example, various embodiments can implement an EBB region or layer comprised of implanted fluorine ions having a peak concentration located slightly below the heterojunction or interface with respect to the design or prospective location of a HEMT gate.

[0014] Negatively charged fluorine ions can also be introduced into the electronic devices to increase the local potential barrier, according to further aspects of the disclosed subject matter. As a non-limiting example, the fluorine treated locations or regions can be in the area of the source-gate access region, gate-drain drift region, source region, drain region, and the gate region. As a further example, fluorine ions can be introduced into the barrier layer and the buffer layer.

[0015] Thus, in further non-limiting embodiments, the provided structures can be combined with Low Density Drain (LDD) fabrication methods to provide a EBB/LDD combination HEMT (e.g., an EBB/LDD HEMT) heterostructure that can further improve the electric field distribution. Further non-limiting embodiments can include an EBB layer or region such that the EBB layer or region is extended substantially to the source region to further improve source-drain isolation in the HEMT "off-state."

[0016] In addition, according to various aspects, fluorine ions can be introduced into the devices using one or more processes including plasma treatment, plasma immersion ion implantation, and ion implantation, and can be combined with the traditional field plate techniques, including gate, source, drain and multiple field plates to further improve the breakdown voltage of electronic devices. As a further advantage, other nitride based electronic devices can employ various embodiments of the disclosed subject matter to increase the local potential barrier, including Metal Semiconductor Field Effect Transistors (MESFETs), Metal Insulator Semiconductor High Electron Mobility Transistors (MISHEMTs), Metal Insulator Semiconductor Field Effect Transistors (MISFETs), lateral field-effect rectifiers (LFETs), light emitting diodes (LEDs), and laser diodes (LDs).

[0017] These and other additional features of the disclosed subject matter are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The devices, structures, and methodologies of the disclosed subject matter are further described with reference to the accompanying drawings in which:

[0019] FIG. **1** depicts a schematic cross section view of a conventional AlGaN/GaN HEMT, in which off-state breakdown mechanisms in AlGaN/GaN HEMTs are illustrated;

[0020] FIG. **2** depicts a schematic cross section of a conventional and an EBB AlGaN/GaN HEMT, according to an exemplary non-limiting embodiment of the disclosed subject matter;

[0021] FIG. **3** depicts an alternate schematic cross section of a conventional and an EBB AlGaN/GaN HEMT, according to an exemplary non-limiting embodiment of the disclosed subject matter, in which the EBB layer or region is more accurately depicted as a continuum of fluorine ion concentrations in the EBB rather than as sub-regions of discrete concentrations;

[0022] FIG. **4** illustrates a test configuration for three terminal off-state breakdown of AlGaN/GaN HEMTs;

[0023] FIG. **5** depicts three terminal off-state breakdown characteristics of an exemplary conventional HEMT at different gate biases;

[0024] FIG. **6** depicts a comparison of breakdown voltage at three- and two-terminal test configuration;

[0025] FIG. **7** depicts the three terminal off-state breakdown characteristics of a conventional high electron mobility transistor as measured by a typical drain-current injection measurement;

[0026] FIG. **8** depicts an exemplary non-limiting electron potential energy distribution in the GaN buffer layer as a function of relative position (X) and at different depths from the channel under an exemplary conventional AlGaN/GaN HEMT gate according to various aspects of the disclosed subject matter, in which the simulation results are depicted using the Synopsys® Santaurus simulator;

[0027] FIG. **9** depicts simulation results of off-state potential energy distribution and electric field vectors under an exemplary non-limiting gate region, according to various aspects of the disclosed subject matter, in which the simulation results are depicted using the Synopsys® Santaurus simulator;

[0028] FIGS. **10-11** depict three terminal off-state breakdown characteristics of an exemplary conventional AlGaN/GaN HEMT with different gate lengths, in which current from source and drain are depicted in FIG. **10** and the gate current is depicted in FIG. **11**;

[0029] FIGS. **12-13** depict three terminal off-state breakdown characteristics of an exemplary conventional AlGaN/GaN HEMT using drain-current injection, in which drain-source voltage and gate current are depicted in FIGS. **12** and **13**, respectively;

[0030] FIGS. **14-15** depict three terminal off-state breakdown characteristics of an exemplary conventional AlGaN/GaN HEMT using drain-current injection, in which drain-source voltage and gate current as a function as V_{GS} (e.g., voltage relative to the device gate and source) are depicted in FIGS. **14** and **15**, respectively;

[0031] FIG. **16** depicts three terminal off-state breakdown characteristics of an exemplary fabricated HEMT at various temperatures;